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AUTHOR Allen, Charles W.
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ABSTRACT

Based on a workshop presented by Charles Wales, a guided design project was developed for a junior mechanical design class at California State University-Chico. This course involves lectures on the design process and an extension of the basic mechanics of materials concepts, particularly as related to design and prevention of failure. The objective of the project was to develop an orthotic arm aid for paralytics which was to be operated largely under programmed control. The process included steps relating to goal establishment, information gathering, component analysis and possible solutions, constraints, choice, and analysis/synthesis. The project was completed by groups of 4 students, who met for a weekly, 2-hour activity period for 5 weeks. A group-written report and an oral report were required. The project was relatively well received, i.e., most students were enthusiastic, but wanted to be "spoon-fed" more. Appendices contain a detailed explanation of the principal components of the design, a summary of the project evaluation, and students' individual evaluative comments. Three references are listed. (LMM)

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INTRODUCING A NEW GUIDED DESIGN INTO THE CLASSROOM

by Charles W. Allen
Professor of Mechanical Engineering
California State University, Chico
Chico, California

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Introduction

In January 1984, Dr. Charles Wales visited California State University, Chico and presented a workshop on guided design. As a result of his presentation, I decided to try guided design in my Spring semester junior mechanical design class. This is a fairly traditional 3-unit class. There is some lecture material on the design process and an extension of the basic mechanics of materials concepts, particularly as related to design and prevention of failure.

In the laboratory, the students usually do a couple of "paper" projects and one requiring the building of hardware. Interspersed in the course are a few case studies.

To introduce guided design in this course, I started with one laboratory period devoted to the "Fishing Trip" (1). Reaction to this was certainly one of surprise and probably some amusement since, being the first class using guided design, they had no inkling that something different was afoot.

At the end of the laboratory period they had finished, and, I believe, enjoyed the project and were certainly in a more open frame of mind with regard to jumping to solutions without a clear concept of the problem.

The Project

Although there are several excellent guided design projects available, none seemed to fit my ideas of the particular class requirements, so I decided to write my own. Requirements for the project were primarily that it be a mechanical design device or system and that it utilize some of the course prerequisite and background material. Searching my background for a project, I decided to use a topic on which I had worked 23 years earlier. This was part of a large project conducted by the Design Center at Case Western Reserve University under the direction of Dr. Reswick.

The objective of the project was to develop an orthotic arm aid for paralytics which was to be operated largely under programmed control. An important part of the project was the mechanical splint structure. The design process was fairly

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well formulated for this project (2) (3). This project involves the interaction of human and mechanical systems, and much of the "experimental" background can be done easily with the student's own body.

The guided design was set up in somewhat the same format as suggested by Dr. Wales. Principal components of the design are given in detail in Appendix A.

The project was designed to last for five weeks. Each section of the class met for an activity period of two hours once per week. Students worked in groups of four, and each group selected one person to serve as group leader.

After completion of the project, the students were required to submit a group written report and an oral report. In spite of the "guiding" aspect of the process, there was considerable diversity in the solutions presented.

The students were requested to make an evaluation of the project. Results of the evaluation are summarized in Appendix B. Individual written comments are given in Appendix C.

Effect on Subsequent Designs

The next part of the semester was devoted to an original design where the students, again working in groups, were required to produce a preliminary design to reverse the order of a stack of forms after being microfilmed in a local form processing operation. Initially, many of the factors considered in the guided design such as defining the problem, gathering information, etc., seemed to have been learned well, but as the semester progressed, some of the concepts seemed to have been forgotten.

In the final exam, one question was to discuss the design process one would go through to design an auxiliary solar powered device to propel a sailboat when becalmed on a sunny day. A few students were sufficiently astute to note that the statement had already defined a solution, and they then went back to define the problem.

Conclusions

The guided design project was relatively well received. Most students were enthusiastic but, as can be seen from the comments in Appendix C, really wanted to be "spoon fed" a little more. This course is the first time they got away from structured problems and "correct answers".

Although some comments such as spending too long on the wrong

approach, insufficient information, etc., were intended as negative, in my view they are positive since this class is intended to simulate a real design situation and not be a textbook exercise. The approach was, I think, well worth while, and I intend to use this project and to develop another one for this year's class.

REFERENCES

1. Wales, Charles E. and Stager, Robert A., Guided Design, 1977. Pp. 4-15
2. Allen, C. W., "Design Study of an Orthotic Arm-Aid", M.S. Thesis, Case Institute of Technology, Cleveland 1962.
3. Corell, Robert W. and Wijnschenk, Maurice J., Design and Development of the Case Research Arm-Aid, Case Institute of Technology, Cleveland, 1964.

Appendix A

PROJECT I DESIGN OF AN APM AID FOR PARALYTICS

Introduction

Prosthetic and orthotic arm aids for amputees and paralytics have been around for a long time. One of the major problems to be overcome is that of control. In 1950 a group of research engineers realized that many of the natural movements of everyday living are essentially programmed instructions similar to those used in the recently developed digital computers. For example, in drinking a cup of coffee, the motions are largely automatic with some tactile and visual feedback at the start and finish of the cycle.

Using this concept, a contract was obtained to develop an arm aid for paralytics operating largely under programmed control.

The objective of this project is to develop a powered splint structure to place the wrist of a paralytic in any reasonable position to perform tasks of everyday living. The sensors and programming system are to be handled by another group and are not part of this task. Several types of hand-finger systems are available and, therefore, an existing unit can be attached to the wrist of the proposed arm aid.

Feedback 1

Establish Goals

Maybe the problem is not stated correctly in the handout. Objective is to enable persons to perform tasks of everyday living without assistance from another person. Perhaps the best thing would not be to use the existing arm at all but to use an independent robot.

Actually, past experience has shown that individuals react unfavorably to such an obvious external helper. Therefore, the present project will proceed using the person's existing arm and designing a device to locate the wrist as originally stated.

Feedback 2

Gather Information

Who is this to be designed for?

What are position, velocity, acceleration and load requirements?

When is this to be used?

Where is it to be used?

How will it be powered?

Why is this device needed?

Who: Quadraplegics

What: Load Min. 2 lb.
 Max. 5 lb.

Position Sufficient to perform eating
 and similar tasks

Velocity Complete any motion in 3-5
 sec.

Acceleration That which is sufficient to
 attain above velocities

When: Primarily for eating, combing hair, etc.

Where: When patient is seated possibly in a wheelchair.

How: Pneumatic, hydraulic, electric

Why: At present many quadraplegics must be fed by another
 person.

Feedback 3

Component Analysis & Possible Solutions

Component:

Kinematics

Power

Attachment
(shoulder)

Attachment
(wrist)

Possible Solutions:

Same as Human

Pneumatic

Shoulder

Cuff

Independent

Hydraulic

Torso

Combination

Electric

Wheelchair

Feedback 4

Constraints

Device must not injure the person
Should be unobtrusive
Simple to operate
Acceptable to person
Reasonable cost
Failsafe

Feedback 5

Choice

From the component analysis and possible solutions coupled with the constraints and assumptions, the design team arrived at the following conclusions:

1. Attachment to any part of the body for support would be impracticable because of the loads involved and the poor body condition of a quadraplegic. Thus, attachment to a wheel chair was deemed the most satisfactory.
2. With the device attached to a fixed mount other than the body, considerable constraints may be imposed on the kinematics in order to prevent damage to the existing arm because the aid would have to duplicate the arm motions exactly.
3. Because of the difficulty of following the motion exactly, it was decided to duplicate the degrees of freedom of the human shoulder, arm complex but to attach the device at the wrist only. By this means the device follows the existing arm motion somewhat but since the attachment is at the wrist only any tendency to "tear the joints apart" is minimized.
4. The team proceeded on this basis using a maximum end load of 5 lb. and assuming a sinusoidal velocity vs. time function with the objective to completing of all motions in about five seconds or less.

Feedback 6

Analysis/Synthesis

The group of engineers had by this time chosen an arm aid which was attached to the chair and wrist and followed approximately the motions of the human arm but did not constrain it. A preliminary analysis showed that for the five degree of freedom system chosen the elbow motion would be easy but the others would be more complex.

The true shoulder motion is a combination of lifting and rotation in abduction and adduction. In fore and aft motion (Sagittal plane) the motion is much closer to a true rotation. Likewise, rotation about the axis of the humerus is close to a true rotation. Forearm rotation is accomplished by rotation of the radius about the ulna at its distal (far) end.

The combination motion of the scapula and glenohumeral joint in the frontal plane leads to an instantaneous center located somewhat toward the center of the scapula rather than at the center of the glenohumeral joint. Therefore, the axis of rotation of the upper link was taken about this point.

The next link was linked to the first by an axis of rotation approximately corresponding to the true axis of rotation of the glenohumeral joint in the sagittal plane.

Rotation about the longitudinal axis of the upper and lower arm was difficult unless the axis of rotation was moved outside of the human arm. This was the method adopted.

There seemed to be no clear advantage of any one form of power over the other perhaps a combination would be better. An analysis showed that all motions except the upper and forearm rotations were best accomplished by linear activators. The remaining motions were handled by rotary actuators.

Appendix B

EVALUATION OF THE GUIDED DESIGN PROJECT

For each of the following items please circle a number from 1 through 5 depending upon your impressions of that particular item.

1. The project was:

Boring				Interesting	Standard
1	2	3 *	4	5	Deviation
		3.82			0.92

2. The time involved was:

Too Short Too Long
1 2 * 3 4 5
2.81 0.77

3. The feedbacks were:

Too Short				Too Long	
1	2	* 3	4	5	
		2.81			0.82

4. The feedbacks were:

Too General				Too Specific	
1	2	* 3	4	5	0.91
		2.92			

5. What did you learn about the design process from this course?

Nothing					A Lot	
1	2	3	4	*	5	
						0.91
			4.03			

6. What technical knowledge did you gain from this project?

None					A Lot	
1	2	*	3	4	5	1.05
		2.76				

7. Would you recommend that a guided design project be incorporated in future ME 138 classes?

No	1	2	3	4	Strong Yes	
			3.91		5	0.96

Appendix C

EVALUATION OF THE GUIDED DESIGN PROJECT

STUDENT'S COMMENTS

Solutions did not take advantage of new lightweight materials and, therefore, became fairly bulky.

Overall, not bad!

The guiding was very useful in getting the group to realize what was and was not possible with our ideas. This is mostly due to inexperience with real mechanical systems (hands on!).

It was a good exercise for the design process, but due to the nature of the problem, I always felt unsure about the right approach since I don't know much about artificial limbs.

The project had too many unknowns because we were dealing with the human body. We should have designed something that was not dependent on the human anatomy.

More of an all around class discussion could be incorporated in addition to group discussion. For example, learning from another group's design by following each other's progress would be valuable too. Next time, a much less sophisticated project would be more desirable, because the actual design could be more detailed.

This kind of design involves complexity for beginning engineers, I think. I suggest that you introduce simpler design projects to begin with. The gathering of the group also didn't produce so much result. Other techniques should be introduced.

A little more guidance might have been needed to keep the group on the right track. Also, a short lecture on format of group lab reports might be helpful in future classes.

The objective (i.e., design thought process) was not very clear. It seemed that the objective was to actually design the mechanical arm.

A guided design project would be helpful in future classes, but the mechanical arm was not a good choice. Also, the instructions could have been more clear.

The written part involved writing down processes of thought that a person does without realizing it.

I learned how to work with a group better.

This is a good way (strong yes) to learn about the "design process".

I learned more of what to consider in a design and about the stipulations and criterion that must be met.

There could be a little more instruction in presenting oral reports.

Require a little more analysis and evaluation of final design.

We did not have enough knowledge of body mechanics to complete this project without research.

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